

JOINT INSTITUTE FOR ADVANCEMENT OF FLIGHT SCIENCES

Program of Research in Flight Dynamics in the
JIAFS at NASA Langley Research Center

NASA Cooperative Agreement NCC1-326

Annual Status Report

December 1, 2000 - November 30, 2001

School of Engineering and Applied Science

The George Washington University

Washington, DC 20052

OVERVIEW

The program objectives are fully defined in the original proposal entitled “Program of Research in Flight Dynamics in the JIAFS at NASA Langley Research Center,” which was originated March 20, 1975, and in the renewals of the research program from December 1, 1999 to November 30, 2000.

The program in its present form includes three major topics:

1. the improvement of existing methods and development of new methods for wind tunnel and flight test data analysis,
2. the application of these methods to wind tunnel and flight test data obtained from advanced airplanes,
3. the correlation of flight results with wind tunnel measurements, and theoretical predictions.

The Principal Investigator of the program is Dr. V. Klein. Two Graduate Research Scholar Assistants (B. R. Monzon and L. Gould) also participated in the program.

SPECIFIC DEVELOPMENTS

Specific developments in the program during the period December 1, 2000 through November 30, 2001, included:

1. Aerodynamic characteristics of the F-18 Aircraft:

The flight test experiment on the F-18 aircraft was again postponed. No new date has been set yet.

2. Aerodynamic characteristics of highly swept delta aircraft:

- (a) An alternative to traditional single-frequency forced-oscillation wind-tunnel testing was proposed. It utilizes a multi-frequency Schroeder sweep to obtain the frequency response of the unsteady aerodynamic model. Schroeder input provides signals with a flat power spectrum over a specified frequency band. Example time histories of the angle of attack, α , lift coefficient, C_L , and pitching-moment coefficient, C_m , is given in figure 1. The harmonic content of the angle of attack is shown in figure 2. The data were obtained by testing a model of the F-16XL aircraft in the NASA Langley 12-foot Wind Tunnel. For data analysis a transfer function model that includes unsteady aerodynamics was developed. The parameters in the model were estimated by the maximum likelihood method in the frequency domain. The methodology in the study compares well with previous studies that used different techniques. However, the previous techniques made different assumptions about a priori information. They assumed that some of the parameters were known. The present approach has the advantage that all unknown parameters in the model are estimated at once for each angle of attack. The results are reported in the AIAA paper.
- (b) Data from the wind tunnel experiment on the 18% scale model of the F-16XL aircraft were collected for the analysis. Then data were obtained from static and oscillatory tests in the 14x22 foot NASA Langley Wind Tunnel. The static data included aerodynamic coefficient for the angles of attack from 0° to 90° and sideslip angle from 0° to 50°. The one-degree-of-freedom oscillatory tests in roll and yaw were

conducted for a range of frequencies, angles of attack, amplitudes and offsets in the initial roll angle.

A model postulated for static data was based on orthogonal polynomials. The parameters in the model were estimated by a linear regression. From the identified model the derivatives of aerodynamic coefficients with respect to sideslip angle, and their variation with the angle of attack were calculated.

The harmonic analysis was applied to the oscillatory data with the amplitude of 5° .

The in-phase and out-of-phase components of the steady harmonic motion were obtained as a function of the angle of attack and frequency. As an example the in-phase and out-of-phase components for the rolling motion are presented in figure 3.

- (c) Two MATLAB programs for an efficient computing of harmonic coefficients were developed. Program “esemble.m” selects runs from repeated measurements suitable for data analysis. Program “cycle.m” provides accurate count of cycles in the time histories selected.

3. Aerodynamic characteristics and simulation of the Radio Control Airplane Dynamics and Control Testbed.

FASER (Free-flying Aircraft for Subscale Experimental Research) is a remote control airplane that will be used as a testbed for research conducted by the Dynamics and Control Branch. The airplane chosen for FASER is the Ultra Stick, which has a span of 6.33 feet, a 1.45 foot chord, and an overall length 4.74. Part of the project consists on developing a nonlinear simulation of the airplane.

The moments of inertia and the product of inertia of FASER were determined from measured data using three-filar pendulum method. The results had to be corrected to account for air damping. In the next step, a procedure for estimation of systematic and random errors which might corrupt the measured values was developed.

The final results were reported in terms of the mean values and uncertainty. The uncertainty was expressed as the sum of credible bounds on systematic errors and two-times the estimated standard error. The final results are in Table I for all three moments of inertia about the body axes Oxyz and the product of inertia I_{xz} .

The estimated mass, inertia, aerodynamic and propulsion characteristics of FASER are summarized in a thesis submitted. Included also are: a MATLAB program to calculate the stability and control derivatives and propulsion effects, a complete simulation program and description of graphical interface tied to a head-up display, a mouse input, and a set of strip charts that display the response of the aircraft.

PUBLICATIONS

1. Monzon, Byron R.: Non-Linear Simulation Development for a Sub-Scale Research Airplane. M.S. Thesis, 2001, The George Washington University, Washington, D.C..
2. Murphy, Patrick C. and Klein, Vladislav: Estimation of Aircraft Unsteady Aerodynamic Parameters from Dynamic Wind Tunnel Testing. AIAA Paper 2001-4016, 2001.

Table I. Mean values of moments of inertia and uncertainty components

	Mean Value (slugs-in ²)	Systematic Error (ΔI_R), %	Random Error (σ), %	Uncertainty ($ \Delta I = \Delta I_R + 2* \sigma $), %
I_x	64.25	3.37	1.29	5.96
I_y	74.36	2.30	0.96	4.21
I_z	133.66	1.56	0.72	2.99
I_{xz}	5.79	3.17	1.00	5.18

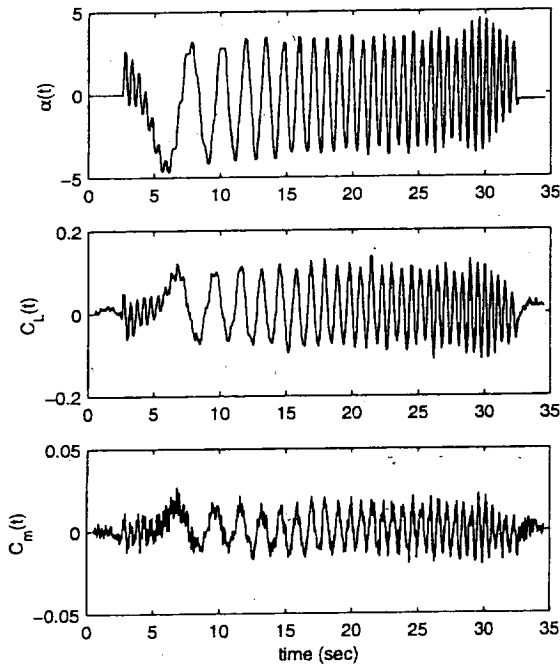


Figure 1. Time histories of angle of attack, lift pitching-moment coefficients.

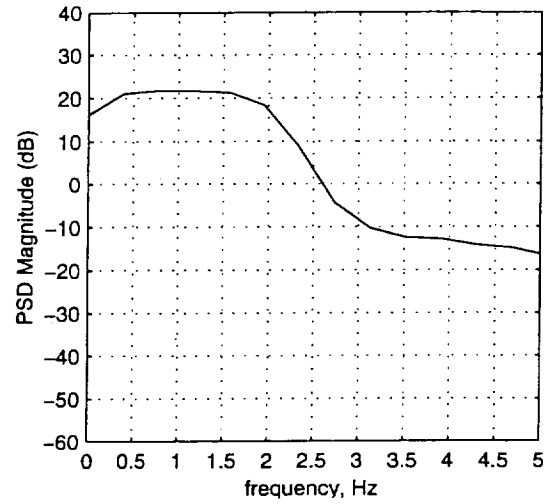


Figure 2. Harmonic content of transformed angle of attack.

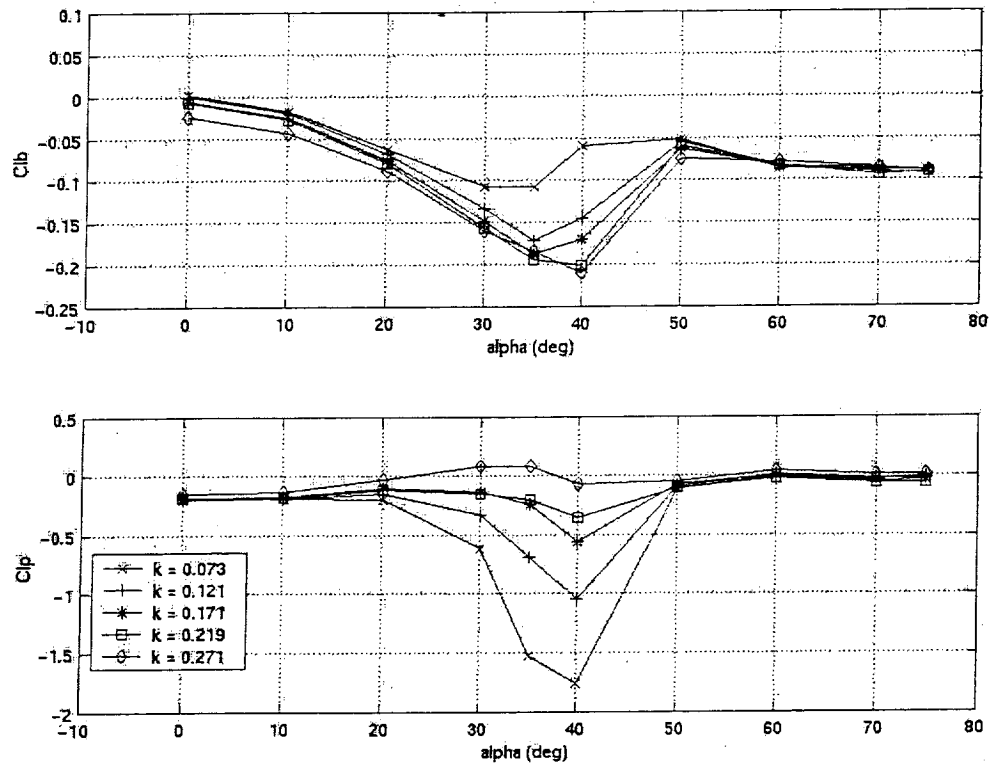


Figure 3. Variation of in-phase and out-of-phase components of rolling motion with angle of attack for five frequencies.

